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REDUCING MORTALITY IN OLD-GROWTH NORTHERN HARDWOODS THROUGH PARTIAL CUTTING

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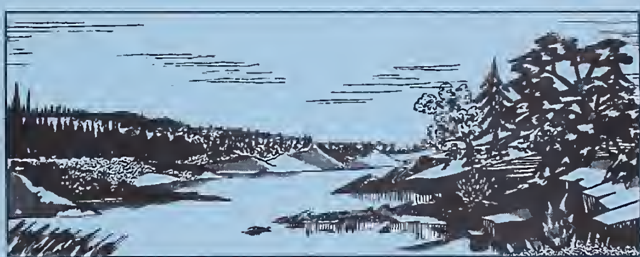

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REDUCING MORTALITY IN OLD-GROWTH NORTHERN HARDWOODS THROUGH PARTIAL CUTTING 2/

By F. H. Eyre and F. R. Longwood 3/

INTRODUCTION

To convert uncut old-growth stands of northern hardwoods to a thrifty forest through partial cutting it is necessary both to provide growing space for promising trees and to reduce mortality. If the mortality normal in a virgin stand is not checked through proper cutting, there may be very little net growth. How then should cutting be done to stimulate growth and at the same time decrease the mortality rate? Recently mortality has been studied on experimental fellings carried out since 1926 in old-growth stands containing a high percentage of cull on the Upper Peninsula Experimental Forest, Dukes, Michigan. This analysis of experience records, collected incidental to general growth studies, provides some answers to the question.

SOURCES OF INFORMATION

This study was based on several sources of information. The data which are most precise and of longest record are from permanent sample plots aggregating 24 acres and dating from 1926. They sample 8 cutting units, varying in size from 5 to 32 acres, and an uncut area.

Because there was some apprehension that the losses might not be fairly represented on small sample plots, mortality records were maintained on the entire cutting units beginning in 1929. A 100-percent tally was made annually, and each year, as new units were cut over, they were added to the study. This was continued the first 7 years with one final tally at 12 years. A 40-acre uncut reserve area that had been established in 1928 for studying mortality and a similar 10-acre uncut area were also included. Altogether the area involved in this study was 175 acres. This constitutes the second source of data.

1/ Maintained at University Farm, St. Paul 1, Minnesota, in cooperation with the University of Minnesota.

2/ Appreciation is extended to E. L. Mowat who maintained the records during the early years and to J. R. Neetzel who was in charge of the experimental area from 1931 to 1941, inclusive.

3/ Forester in charge, Division of Forest Management, and Forester, Upper Peninsula Forest Research Center.

A third source is the 472 permanent inventory plots which were installed during 1940, 1941, and 1942 on the enlarged experimental forest as it was being placed under management. These were fifth-acre plots, on which all trees were diagrammed on map sheets. The area involved was 94 acres. About 70 percent of these plots were on areas which had been given a light improvement cut; the majority of the others were on areas uncut except for salvage of dead trees. These records are available for an average period of a little over 6 years.

The first two sources of data apply almost exclusively to areas of northern hardwoods in which hemlock and beech are absent. The third includes some hemlock and hardwood swamp (ash-elm type). Only trees devoid of green foliage were considered dead; trees with even one green branch remaining were classed as living.

PERMANENT SAMPLE PLOT RECORDS

Mortality and growth records are available for a 20-year period for most of the permanent sample plots. The data resulting from the analysis have been grouped into several categories mostly in accordance with the stocking left at the time of cutting (table 1). In these cuttings the timber markers made an effort to designate the more defective trees for removal, although they marked chiefly the larger trees. However, marking varied somewhat from plot to plot in accordance with specific objectives. In the analysis of data gross mortality in each cutting was reduced to net mortality by applying the estimated average cull percent for all residual trees in the stand. Since the proportion of defect in the trees that died was likely greater than in the remainder of the stand the net mortality volumes may be somewhat inflated. The group-selection cutting is a special case in which only patches in the stand were cut rather than the whole area. In between the patches few trees were removed.

The analysis of the records brought out that board-foot mortality was highest in the uncut reserve area which had a stand volume of 9,300 board feet net. The next highest loss was in the group-selection cuttings (8,200 board feet net residual stand). This was probably due to the failure to remove very many trees of poor risk between the clear-cut patches.

The loss in the lightly-cut plots was almost identical with that on the group-selection area. Here again there was insufficient opportunity to remove poor trees. The heavy cuttings (2,300 board feet net after cutting) were fourth in mortality. Such losses as were sustained can be attributed in part to too much exposure and to injuries caused by logging operations. The heavier the cut the more likely are the trees to be damaged. In the intermediate cuttings (4,700 board feet net after cutting) loss was least of all. Here the cutting was heavy enough to remove many poor-risk trees but not so severe as to cause much loss from exposure and logging damage. The most striking fact brought out, however, was that the average mortality on all cutting plots was only one-fourth that in uncut timber.

Mortality should not be considered apart from growth. Thus it is interesting to compare net growth with mortality (table 1). The best net growth occurred where mortality was the least. This was so even though these cuttings (intermediate) had much less growing stock on which to add increment than some other cuttings.

Trends in mortality were about the same whether considered in basal area or as board-foot volume. In all cases except one, over 80 percent of the loss in basal area was in trees 10 inches d.b.h. and larger.

The stands in which permanent sample plots are located consist of over 90 percent sugar maple, about 6 percent yellow birch, and the balance of mixed species on the basis of the number of trees above 10 inches d.b.h.[4] Yellow birch has the reputation of being a sensitive tree, and this was borne out in the cutting. Birch suffered somewhat more mortality proportionately than did the sugar maple.

Sugar maple made up 98 percent of all mortality on light and intermediate cuttings as compared to 99 percent on the reserve area, 91 percent on the group selection cutting, and 75 percent on the heavy cuttings. Yellow birch comprised only 2 percent of the mortality on light and intermediate cuttings, 9 percent on the group-selection cutting, and 20 percent on the heavy cuttings. The balance of the loss occurred in elm and balsam fir. It is evident that yellow birch suffers more from heavy cuttings than sugar maple. On light and intermediate cuttings, birch appeared to be as good a risk as maple. Hall[5] attributed mortality losses to changes in physical factors of environment. Results here support this observation for yellow birch but not for sugar maple. In the case of maple, the condition of the tree appears to be much more of a factor in its survival after cutting than any change in environment. An exception is the extremely heavy cuttings. Even here many of the maples that died in the tops recovered later. Sugar maple is a tough tree. Fortunately, it is the one having the greatest volume in the northern hardwoods of the Lake States.

A tally of losses according to whether the trees died standing, were broken off, or were uprooted showed that breakage was the most common type of loss (table 2). In this grouping, breakage, though very important, may be slightly exaggerated because some trees die on the stump and then break off later. Thus in cases where the examination was not made soon after death it was not always possible to place the tree in the right group. Breakage of living trees usually occurred where there was some major defect on the bole or on a large limb. Defects such as butt rot, large seams or frost cracks, cankers, burls, defective scars, and hidden decay make trees susceptible to breakage. Trees that broke off were generally more defective than trees that died standing or were uprooted.

4/ Yellow birch and mixed species make up a considerably larger proportion in the other study area described later in the report.

5/ Hall, Ralph C. Post Logging Decadence in Northern Hardwoods. Univ. of Michigan School of Forestry and Conservation, Bul. No. 1, 66 pp., illus., 1933.

Table 1.- Annual mortality per acre compared to growth on permanent sample plots

Kind of cutting	Basal area per acre 1/ 2"+	Basal area per acre 1/ 10"+	Annual mortality Gross	Annual mortality Net	Annual mortality Basal area gross	Annual growth Gross 2/	Annual growth Net 3/
	Sq.ft.		Bd.ft.		Sq.ft.	Bd.ft.	
Reserve (Plot 1)	134	118	153	97	1.23	70	44
Light (Plots 2,3,17)	98	83	43	34	.35	235	186
Intermediate (Plots 9,16,41)	4/62	52	10	8	.10	254	200
Heavy (Plots 10,11,33)	4/41	34	22	17	.22	217	172
Group selection (Plots 22,23,25)	92	83	46	35	.35	170	130

1/ At time of plot establishment. The percent of gross volume removed in the first four of these units was respectively 0, 28, 55, and 75.

2/ Mortality has been deducted but not cull.

3/ Reduced for mortality and also for estimated cull in stand. In the cuttings cull varied from 15 to 24 percent and was 37 percent in the uncut reserve plot.

4/ For trees 5 inches and over for plots 41 and 33.

Table 2.- Percent of average annual mortality in gross volume by type of loss on permanent sample plots

Kind of cutting	Dead standing	Broken	Uprooted	Total
		Percent		
Reserve	13	76	11	100
Light	21	77	2	100
Moderate	46	54	0	100
Heavy	28	32	40	100
Group selection	48	50	2	100

Approximately 60 percent of the maple and birch mortality occurred when trees were broken over. This indicates the underlying cause of death, such as rot, frost cracks, large burls, or other defects, was present before cutting. Some 30 percent of the maple and birch mortality was in trees that died standing. No attempt was made to assess the cause of their death. Uprooting was not a serious threat to residual trees as it caused only 10 percent of the loss. It was much less of a hazard than some foresters believe. The major species in the hardwood stands of the Upper Peninsula are well rooted and reasonably resistant to windthrow from ordinary storms6/ except on wet or shallow soils. Only in stands of very light residual stocking which had been opened up severely were the windfall losses appreciable.

Mortality occurred in all diameter classes. The average tree dying in the sawlog class, regardless of species, was slightly over 16 inches d.b.h. An average of 150 board feet, net, was lost in each tree that died.

The mortality was compared for four five-year periods on the various cuttings. The losses in the intermediate cuttings showed a slight decrease from period to period while those in the heavy cuttings lost more heavily at first and then remained rather constant. In the light cuttings there was a tendency for a build-up in mortality during each five-year period following cutting as these stands filled up and took on more the characteristics of an uncut forest.

SPECIAL MORTALITY STUDY IN CUTTING UNITS AND RESERVE AREAS

The special mortality study of all cutting units and reserve areas started out to be a 100-percent annual check of all trees that were lost for any reason. Before the study began all dead trees were marked so as not to confuse them with trees which might die subsequently. A tally of dead trees was made each spring just as leaves began to come out so that living and dead trees could easily be distinguished while visibility was still good.

By 1934 the annual cruise of mortality had become too large a job to handle with the available help. It was therefore placed on a periodic basis of 5 years after which it was discontinued. The last field tally was made in 1940. Annual records are available for 7 years, together with a periodic record for 5 years. For purposes of analysis the data were split into two 6-year periods by adding the last annual check to the 5-year periodic tally. No exact comparison with growth is possible on these areas although the permanent sample plots (table 1) give growth for samples on these cutting units.

The analysis disclosed that annual net loss on uncut areas was from 62 to 100 board feet per acre (table 3). It was thus three to five times that on the average cutting unit. Mortality was less the second 6-year period

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6/ They are not resistant, however, to winds created by tornadoes.

Table 3.- Annual mortality in board feet per acre by large cutting units during two six-year periods

Unit	Area in study	Proportion of gross saw-timber volume removed	Annual loss per acre					
			1929-1934 inc.		1935-1940 inc.		1929-1940 inc.	
			Gross	Net	Gross	Net	Gross	Net
	Acres	Percent	Bd.ft.		Bd.ft.		Bd.ft.	
Reserve (checks)								
Reserve No. 1	10	0	108	68	89	56	99	62
Reserve No. 2	40		159	100	(1/)	(1/)	(1/)	(1/)
Light cuttings								
Unit No. 1	19	20-30	56	45	32	26	44	35
Unit No. 6	8		43	33	47	36	45	34
Inter. cuttings								
Unit No. 2	10	50-60	9	7	2	2	6	5
Unit No. 5	8		16	12	17	13	16	12
Unit No. 9	13		(2/)	(2/)	9	8	(2/)	(2/)
Heavy cuttings								
Unit No. 3	5	70-90	20	16	15	12	17	13
Unit No. 8	30		3/88	3/70	14	11	4/48	4/38
Special group selection								
Unit No. 7	32	40	3/32	3/24	25	19	4/28	4/21

1/ Record dropped for second period because of road construction in the area.
2/ Not established until second period.
3/ Five-year record.
4/ Eleven-year record.

than in the first in almost all cutting units and in the check area. This may be attributed at least in part to generally more favorable precipitation during the second period. On the heavy cuttings there was some die-back in tops which did not result in mortality. After a period of adjustment many such trees built up new crowns. The location of the area under observation also was a factor. For example, in unit 6, which was more exposed to the wind than other areas, the loss was quite heavy. Some of this loss was in balsam fir situated along the edge of a swamp.

The losses in the various cuttings varied considerably. Probably the most significant observation is that the cuttings in which an intermediate stocking was left, especially Nos. 2 and 9, where a special effort was made to eliminate all defective trees, showed the lowest mortality. On the latter, however, some fuelwood had been removed before the study started and this may have contributed in part to its good showing. The highest mortality in most cases was in units where there was least emphasis on removal of trees of poor risk.

In general the average results on the cutting units agree exceptionally closely with those obtained on the permanent sample plots. Since the sample in the special study involved a considerably larger area than the plots, the results strengthen those given in table 1. The average mortality in partial cuttings (table 3) has not been much over 20 board feet per acre per year which, as shown by sample plot data, has been greatly exceeded by the growth. Due to the lack of specific information, trees that died were considered to have the same percent of cull as the remainder of the stand. Actually, trees that succumbed probably had more defect than those that survived. Consequently, the net mortality losses may be slightly less than shown in the text and tables.

DIAGRAMMED PLOTS

In 1938 a plan was put into effect to place under management a tract of 5,000 acres consisting of the major portion of the Upper Peninsula Experimental Forest. A light improvement cut was to be applied with the objective of salvaging trees of poor risk and low growth potential during a 10-year period. The cutting removed on the average some 1,200 to 1,300 board feet per acre, net, in the hardwood and ash-elm types and from 2,000 to 3,000 board feet per acre, net, in the hemlock-hardwood and pure hemlock types. In some cases the cut merely salvaged the dead trees.

In order to determine growth, 1/5-acre diagrammed plots were laid out in the cutting units. This program was followed as cutting progressed during 1940, 1941, and 1942, when it had to be discontinued for lack of necessary funds. By that time 556 plots had been established, 393 of which were in areas covered by a light improvement cutting and 79 in areas never cut except for the salvage of dead trees. The latter constituted check areas for the cutting units. On these diagrammed plots each tree was mapped and individual tree records maintained by species and diameter. In 1948 all

diagrammed plots were remeasured as a part of a recruise of the tract. Eighty-four of the 556 plots were not used in this study because of re-cutting or because they were transitional as to timber type and could not be properly classified.

The availability of these diagrammed plots presents the first opportunity on the Upper Peninsula Experimental Forest at Dukes, Michigan, to compare mortality in pure northern hardwoods with mixtures in which hemlock is an important component and with the wet ash-elm type. Where a light improvement cut had been made in the northern hardwood type 34 board feet per acre were lost annually, compared with 120 board feet for the plots from which no green timber had been removed (table 4). Annual net growth in the cut hardwood type averaged better than 70 board feet per acre after mortality was deducted. It is assumed that mortality and net growth were about in balance in the uncut hardwood type.

Mortality in the partially-cut hemlock type averaged 166 board feet, net, per year (table 4). This was approximately equal to growth on this type. The transitional hardwood-hemlock type and ash-elm occupied intermediate positions having an average annual net mortality of 72 and 85 board feet respectively. In both of these types net growth considerably exceeded mortality.

The loss in the partially-cut hardwood area agreed closely with that shown by the other studies (tables 1 and 3) where a similar light type of cutting prevailed and thus supports previous conclusions. The light cutting employed did not remove sufficient trees of poor risk, but it did reduce the loss very strikingly over the uncut area. Partially-cut hemlock, unless in thrifty stands, has generally been recognized as being susceptible to heavy mortality. These overmature stands are no exception. In a special study of hemlock Graham[7] found that after partial cutting, hemlocks with heavy crowns suffered loss from exposure than those with small crowns and that the decadence was in proportion to the amount of exposure. He felt also that direction of exposure was significant and that hemlock and birch should be protected on the south and west by more hardy species.

Mortality in trees below sawlog size (5-9 inches d.b.h.) constituted about 10 percent of the total loss in basal area on both the partially-cut hardwood stands and those subjected to a salvage cut of dead trees. The loss in small trees on the partially cut hardwood-hemlock and hemlock types averaged 13 and 9 percent respectively of the total loss in basal area. In all types the loss in trees below sawlog size amounted to an average of less than one 7-inch tree per acre annually. The loss in pole-size trees by types generally followed the same trend as sawlog trees except in the ash-elm type where nearly 20 percent of the total loss in basal area was in trees of this class. This probably is due to the relatively large number of pole-size trees in the ash-elm stands.

7/ Graham, Samuel A. Causes of Hemlock Mortality in northern Michigan. University of Michigan School of Forestry and Conservation. Bul. No. 10, 61 pp., 1943.

Table 4.- Annual net mortality per acre by types and species after light improvement cutting on diagrammed plots

Type	Basis: plots	Annual net mortality									
		Sugar maple	Yellow birch	Hemlock	Red maple	Elm	B. fir W. spruce	No. white cedar	Black ash	Misc.	Total
	Number	Board feet									
Northern hardwoods (cutover)	253	20	9	1	1	2	-	-	-	1	34
Northern hardwoods (check) 1/	79	65	31	14	8	1	-	-	-	1	120
Hardwood-hemlock	121	9	15	36	11	-	-	-	-	1	72
Hemlock	11	-	-	127	22	-	17	-	-	-	166
Ash-elm	8	-	-	20	13	-	-	18	34	-	85

1/ Also referred to in text as uncut or salvage cut as only dead trees were removed.

The dead sawlog-size trees were rather uniformly spread over all diameter classes. As a result board-foot losses increased in the larger diameters. Most mortality was represented by standing dead trees except in the ash-elm type where broken-over trees were most numerous. Seventy-one percent of all mortality in the lightly-cut hardwood type occurred in standing dead trees, comparing closely with the 76 percent in the uncut (salvage only) hardwood stands. However, 26 percent of the mortality on lightly-cut hardwood stands occurred in broken-over trees, compared to 4 percent in the uncut areas. This may be the result of the removal of only part of the poor risk trees by the light partial cutting which at the same time opened up the stands sufficiently for wind to break over many of the remaining defective trees. These trees generally broke off at a point along the trunk, usually near the butt, due to some defect. The stands treated by a salvage cut also have many high-risk trees but they were not subjected to added wind stresses through partial cutting of live trees.

Only 3 percent of the mortality on the cut hardwood stands occurred in uprooted trees, compared to 20 percent on the uncut (dead-tree salvage) stands. This can be attributed largely to the policy, in the partial cutting, of removing many large leaning trees and others subject to windthrow. The men marking trees for cutting at Dukes have paid particular attention to this feature. In addition, part of the salvage-cut stands were on a relatively wet site subject to heavy windthrow.

In the transition hemlock-hardwood type 63 percent of the mortality occurred in standing dead trees, 21 percent was in trees that broke off and 16 percent occurred through windthrow. In the hemlock type proper, 87 percent of the mortality was in standing dead trees, broken-over trees accounted for 10 percent, and uprooting contributed only 3 percent of the loss. Hemlock is relatively wind-firm, but residual trees often die standing soon after logging. After death maple sometimes breaks off, but birch does so only occasionally, and hemlock, scarcely at all. In the ash-elm type 65 percent of all mortality occurred in broken-over trees. This may be explained by the characteristic tendency for advanced butt rot to occur in many species in the ash-elm stands.

The division of losses between standing dead and broken-over trees in the upland hardwoods was considerably different from that encountered in the two previous studies. No completely satisfactory explanation is apparent but the latter study was, of course, for a much shorter period and the area may have been subjected to fewer high winds.

The average annual rate of mortality for all species was found to be .42 percent on the cut hardwood type, 1.57 percent on the uncut (salvage only) hardwood type, 1.04 percent on the cut hardwood-hemlock type, 2.16 percent on the pure hemlock type, and 1.41 percent on the cut ash-elm type (table 5). On the cut hardwood type sugar maple lost somewhat less (.31 percent) than the average rate for the type while the percent of yellow birch volume lost annually (.88 percent) was more than twice the average

Table 5.- Percent of residual net volume lost annually through mortality on diagrammed plots

Species	Residual stand volumes 1/ and percent mortality 2/									
	Northern hardwood (cutover)		Northern hardwood (salvage cut)		Hardwood-hemlock (cutover)		Hemlock (cutover)		Ash-elm (cutover)	
	Stand volume	Annual loss	Stand volume	Annual loss	Stand volume	Annual loss	Stand volume	Annual loss	Stand volume	Annual loss
	Bd.ft.	Pct.	Bd.ft.	Pct.	Bd.ft.	Pct.	Bd.ft.	Pct.	Bd.ft.	Pct.
All species	8,033	.42	7,624	1.57	6,938	1.04	7,699	2.16	6,037	1.41
Sugar maple	6,435	.31	4,121	1.58	838	1.07	100	-	155	-
Yellow birch	1,027	.88	1,947	1.59	2,218	.68	732	-	927	-
Red maple	146	.68	323	2.48	1,302	.84	1,293	1.70	876	1.48
Hemlock	84	1.19	778	1.80	2,380	1.51	4,762	2.67	492	4.07
American elm	170	1.18	176	.57	-	-	49	-	140	-
Black ash	-	-	-	-	-	-	205	-	2,987	1.14
White cedar	-	-	-	-	-	-	448	-	250	7.20
White spruce	-	-	-	-	-	-	53	32.08	189	-
Miscellaneous	171	3/ .58	279	3/ .36	200	3/ .50	57	-	21	-

1/ Net board feet per acre in residual stand after cutting.
2/ Percent of net residual volume lost annually through mortality.
3/ Includes small quantities of black ash, white cedar, and white spruce in some instances.

rate for all species. Yellow birch (1.59 percent) and sugar maple (1.58 percent) suffered approximately the same percent of loss annually on the uncut hardwood type and hemlock (1.80 percent) was only slightly higher. On the cut hardwood-hemlock type the percent of sugar maple volume lost annually (1.07 percent) was slightly greater than the average for the type, while yellow birch (.68 percent) and red maple (.84 percent) were somewhat less than the average for the type. However, hemlock mortality (1.51 percent) was one and one-half times the average for all species in the hardwood-hemlock type.

Hemlock suffered rather heavy mortality in all types, indicating it is a high-risk species following partial logging but it was not as vulnerable in the hardwood-hemlock type as has been the experience in some other parts of the Lake States. However, in the partially-cut pure hemlock type, hemlock mortality was 2.67 percent annually. The sample was weak (only 11 plots) but if it is representative then it is apparent that the type of partial cutting practiced here in badly overmature hemlock stands was not successful in reducing mortality. There may, however, be some benefits to reproduction.

The total loss in board feet in the hardwood area is in very close agreement with the other studies (tables 1 and 3) where a similar light type of cutting prevailed and thus lends strength to previous conclusions. The light cutting employed did not remove sufficient trees of poor risk, but it did reduce the loss very strikingly over the uncut area.

SUMMARY AND CONCLUSIONS

In the conversion of defective old-growth northern hardwoods to thrifty forests through partial cutting, it is necessary to reduce mortality to reasonable limits. Good clues as to how this may be done are provided in experience records on the Upper Peninsula Experimental Forest, Dukes, Michigan.

Three sets of data including 24 acres in permanent sample plots dating back to 1926, 12-year records of cutting units aggregating 175 acres and a 6-year record of growth and mortality on 472 inventory plots were available for the study.

Net mortality in uncut stands was found to be approximately 100 board feet per acre per year, almost as much as growth. Over a longer period growth and mortality would probably balance.

In partial cuttings mortality was only 1/5 to 1/3 as great as in uncut stands and was far exceeded by growth. The very light cuttings were not as successful in reducing mortality as were those which were somewhat heavier where there was more opportunity to remove defective trees. Stands cut to an intermediate degree had especially low mortality, less than 10 board feet annually on the average. This was greatly exceeded by growth. The very heavy cuttings lost slightly more than the intermediate ones, due probably to too much exposure of residual trees.

Although most of the data were for pure hardwoods, some information was obtained for a short period on the hemlock and ash-elm types, which had been given a partial cut. The mortality in hemlock was heavy in accordance with general experience in the region, and that in ash-elm was considerably greater than in well-drained upland hardwoods.

Among the various species, sugar maple, the most important component, suffered relatively little loss. Yellow birch upheld its reputation as a sensitive species and lost more proportionately than sugar maple. The mortality rate was much the highest in hemlock.

Losses in hardwoods appeared to be proportional to the amount of defect left in the stand. Mortality can be sharply reduced by partial cutting if proper attention is directed to elimination of defective trees. Except in fairly thrifty stands where cull and trees of poor risk can largely be removed in the first cut, there is usually a need for a salvage program whereby trees that die -- or better yet, those about to die -- can be utilized promptly.